WHITE PAPER

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Updates of Maximum Stand Density Index and Site Index for the Blue Mountains Variant of the Forest Vegetation Simulator[1]

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INTRODUCTION

Land managers use growth-and-yield models to meet many needs, including forest planning at a broad scale (e.g., developing yield tables to estimate future timber production from a national forest) and stand dynamics modeling for project planning at a fine scale. Modeling results provide managers with the estimated effects of stand development resulting from any particular combination of species composition, site productivity, and tree density (stocking).

Historically, some growth-and-yield modelers had little faith in the accuracy of modeling results. A good example of this situation is provided in an excerpt from a Comptroller General report examining Forest Service use of growth simulators:

> "Each of the four national forests we reviewed had developed yield tables using a specifically designed regional computer program. These tables provided the forest managers with estimated harvest yields that could be expected from growing timber of a given species on a given land productivity classification under managed conditions. In making their analyses, forest personnel at three of the four forests made adjustments to the yield tables. They said that the tables did not accurately reflect the timber yield volumes that could be expected from on-the-ground conditions. These adjustments were made, however, with little or no analyses and were based primarily on professional judgment. For example, the forest managers of one forest said that the yield tables reflected yields under ideal conditions and depicted timber stands completely stocked and periodically thinned. They said that actual conditions usually differed. Therefore, they reduced the tables' volumes by about 15 percent to more closely approximate reality. A forest manager said that the amount of the reduction was based on professional judgment, and that no analyses of research or field stud-

[1] White papers are internal reports; they receive only limited review. Viewpoints expressed in this paper are those of the author – they may not represent positions of the USDA Forest Service.

> ies had been made to document its reasonableness. The forest managers of two other forests also assumed that the tables' yield volumes were not realistic and reduced the yield estimates by 10 percent and 21 percent, respectively. As with the first forest, the reductions were based primarily on professional judgment. At the fourth forest the yield table volumes had not been adjusted. The forest manager said that a reduction should probably have been made but that the data needed for a realistic adjustment had not been developed" (Staats 1978, pages 24-25).

Although more confidence in modeling results exists today than historically, mostly because simulation modeling has improved considerably since its infancy in the 1970s, there is still a pressing need for forest managers to adjust simulation parameters to better reflect the specific stand or site characteristics of their planning area.

This report is designed to meet three objectives:

1. To provide updated values of maximum SDI and site index for 10 tree species, by plant association, for the Blue Mountains variant of the Forest Vegetation Simulator.
2. To provide an updated selection of a default species for each plant association for which maximum SDI and site index data is available.
3. To document how updated values of maximum SDI and site index were derived.

BACKGROUND FOR MAXIMUM STAND DENSITY INDEX

Forest managers in the Blue Mountains of northeastern Oregon and southeastern Washington have been using the Blue Mountains variant of the Forest Vegetation Simulator (FVS) since its inception in the early 1990s (Johnson 1990). These managers need a documented basis for adjusting certain parameters influencing modeling results. Perhaps no parameter has more influence on modeling results than tree mortality rates.

In the context of FVS, tree mortality is derived from two main sources: exogenous (external) agents such as insects, diseases, and fire, and endogenous (internal) mortality. Endogenous mortality has two sources: background mortality and density-dependent mortality (Dixon 2009).

Background mortality occurs at low levels and is not necessarily related to stand density. As stocking levels increase, density-dependent mortality becomes more important than background mortality and it will eventually predominate. For dense stands experiencing intense, intertree competition, an ecological process called self-thinning, big trees crowd out small, subcanopy trees and kill them (self thinning and density-dependent mortality are considered synonymous terms).

For the Blue Mountains variant, exogenous mortality caused by insects, diseases, wind, animals, and other factors is accounted for by using keywords to control how it functions in the base model or in extensions to it. Some extensions are embedded in the base model (e.g., dwarf mistletoe impact model), but most extensions (fire & fuels, root disease, bark beetles, spruce budworm, etc.) are executed in tandem with the base model (Dixon 2009).

The Blue Mountains variant uses an SDI-based tree mortality model (Johnson 1990), which means that density-dependent mortality (certainly the more important of the two endogenous mortality sources) is controlled by changes in a stand density measure called Stand Density Index (SDI). SDI-based mortality rates vary in response to the relationship between a stand's existing SDI value and a default or comparison value called maximum SDI (Dixon 2009).

For the Blue Mountains variant, default values of maximum SDI vary by plant association. At the present time, only one maximum SDI value is associated with each plant association, and this single value relates to a particular tree species. Since some plant associations can support all seven of the primary conifer species in the Blue Mountains (Douglas-fir, Engelmann spruce, grand fir, lodgepole pine, ponderosa pine, subalpine fir, and western larch), and because each of these species has its own unique value of maximum SDI, selecting only one maximum SDI value for a plant association requires an assumption about which species best represents the association.

To obtain realistic modeling results, forest managers should adjust the SDI-based mortality factors in the Blue Mountains variant. If the input information for a simulation does not include data about plant associations (by including ecoclass codes), then the Blue Mountains variant will default to a single maximum SDI value (546) for all tree species. From a modeling perspective, this is the worst-case scenario because density-dependent mortality would not vary in response to either plant association or species composition.

More often, a user's input data does include plant association information, in which case FVS will establish an association-specific SDI default value for each stand in the projection file. This default SDI value, however, will be based on a single species for each plant association, and with very few exceptions, the default species is always the climax dominant (i.e., for grand fir associations, the default is the grand fir SDI value; for Douglas-fir associations, the default is the Douglas-fir SDI value; and so forth).

Any stocking analysis is species dependent, so having the Blue Mountains variant default to a single-species maximum SDI value is problematic. Some tree species are more sensitive to overcrowding than others (Cochran et al. 1994, Powell 1999), and it might be important to reflect their stocking relationships when selecting a maximum SDI value to control density-dependent mortality.

Since the maximum SDI default for each association relates to the climax tree (the most shade-tolerant species), forest managers must adjust the default SDI value if they want modeling results to properly reflect density-dependent mortality for non-climax (shade-intolerant) trees. Currently, users implement this adjustment by including a keyword (SDIMAX) to establish a new default value.

IDENTIFYING A NEED FOR MAXIMUM SDI UPDATES

In the fall of 2001, work began on an assessment examining the potential availability of wood products for the Blue Mountains physiographic province. The assessment was directed at identifying densely-stocked stands where thinning could be implemented as a restoration activity while simultaneously providing some level of wood products for commercial uses (Rainville et al. 2008).

The primary data source for the Blue Mountains assessment was a grid-based inventory system called the Current Vegetation Survey (CVS) (USDA Forest Service 1995). The Site Index section below provides additional background information about CVS as a data source.

Densely-stocked stands were identified by using the Blue Mountains variant – if stand density was more than 45% of maximum SDI,[2] the stand was assumed to be densely stocked and thinned back to 35% of maximum SDI. This process relied on maximum SDI because existing density was compared with maximum density when identifying densely-stocked stands, and because densely-stocked stands were thinned to a constant percentage of maximum density.

Since maximum SDI values for climax tree species poorly represent the growing-space requirements of non-climax species such as ponderosa pine or western larch, it was necessary for the assessment's FVS modeler (Ed Uebler) to use keyword files to update maximum SDI values for thousands of CVS plots.

Late in 2006, several of the assessment's analysts asked the Pacific Northwest Region Silviculturist (Bill McArthur) to explore options for updating maximum SDI values for the BM variant. It was hoped that by updating the defaults, wholesale adjustments (using the SDIMAX keyword) would no longer be needed in the future.

The Regional Silviculturist concurred with this request and contacted the Forest Management Service Center (FMSC) early in 2007. [FMSC is the steward of FVS variants and their extensions.] Bob Havis from FMSC then contacted me in January of 2007 and we began discussing how the updates would need to be completed to meet FMSC's requirements.

In late January 2007, a work group was formed to develop updated values of maximum SDI and site index for the Blue Mountains variant of FVS. The work group consisted of the following individuals:

Bruce Countryman, vegetation specialist, Blue Mountains Forest Plan Revision Team (bcountryman@fs.fed.us; 541-523-1452).

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ANALYSIS METHODOLOGY FOR MAXIMUM STAND DENSITY INDEX

Stand density index (SDI) expresses the relationship between a number of trees per acre and a quadratic mean diameter (QMD); SDI is indexed to a QMD of 10 inches (Daniel et al. 1979, Reineke 1933). This means that an SDI of 140 can be the same as 140 trees per acre but only when a stand's QMD is 10 inches; at any other QMD, the density associated with an SDI of 140 would be something other than 140 trees per acre.

[2] Generally, 60% of maximum density would be used as a threshold value for identifying densely stocked, even-aged stands (see table 1). For the Blue Mountains assessment, 45% was selected to account for uneven-aged or irregular stand structures, stocking variability across a stratum, time lags before treatment, and other factors.

When L.H. Reineke developed SDI (Reineke 1933), he plotted tree densities for fully stocked, even-aged stands and then drew a freehand line skimming the outermost data values, such that all size-density points fell below the curve (fig. 1). This outermost boundary line represents maximum density and if Reineke's sample of fully-stocked stands was reasonably comprehensive, then the maximum density line is a threshold that will not be breached – areas to the right of the line function as a "no-go" area in terms of stand density.

Suggested stocking levels for the Blue Mountains were published in a 21-page research note from the Pacific Northwest Research Station in April 1994 (Cochran et al. 1994). The Cochran note includes stocking levels for two geographical portions of the Blue Mountains ecoregion: the Blue-Ochoco physiographic province (Johnson and Clausnitzer 1992), and the Wallowa-Snake physiographic province (Johnson and Simon 1987). Stocking levels are presented separately for the two provinces (as tables 3 and 4 in Cochran et al. 1994).

In the Cochran note, suggested stocking levels are expressed as stand density index (SDI). The plant association field guides presented stocking information as growth basal area (GBA) (Hall 1989), so the Cochran group needed to convert the GBA values into their corresponding SDI values before developing the suggested stocking levels. The mathematical process for how GBA was converted to SDI is described in Cochran et al. 1994 (pages 5-7).

When considering tables 3 and 4 from the Cochran note, suggested stocking levels are provided for a total of 66 plant associations. The tables also include stocking levels for seven conifer species: Douglas-fir, Engelmann spruce, grand fir, lodgepole pine, ponderosa pine, subalpine fir, and western larch. This level of detail makes the Cochran research note unique because suggested stocking levels are provided for 462 possible combinations (66 plant associations × 7 tree species = 462 SDI values). Not all of these combinations actually exist because it is relatively uncommon to have every species occur on every plant association.

The Cochran note presents suggested stocking levels using one stand density benchmark or threshold level – full stocking. What is full stocking, and why did the Cochran group select it as their reference level?

The Cochran note provides Blue Mountain land managers with an ecologically appropriate basis for establishing sustainable stocking levels. The ecological appropriateness was assured by using potential vegetation (plant association) as an indicator of "carrying capacity" for tree density (i.e., moist-site associations can support more density than dry-site associations). The sustainability basis was met by establishing a relative density reference level, which allows managers to design sustainable density management regimes by establishing upper and lower limits of a "management zone" located below the unsustainably high density level of full stocking.

The Cochran note did not provide explicit SDI values for the upper and lower limits of a management zone, but it described how managers could calculate them (Cochran et al. 1994, pages 7-10). Why did the Cochran note use full stocking (normal density) as its reference level instead of selecting maximum density for this purpose? The answer is simple – to be consistent with national Forest Service policy regarding development of stocking-level guides.

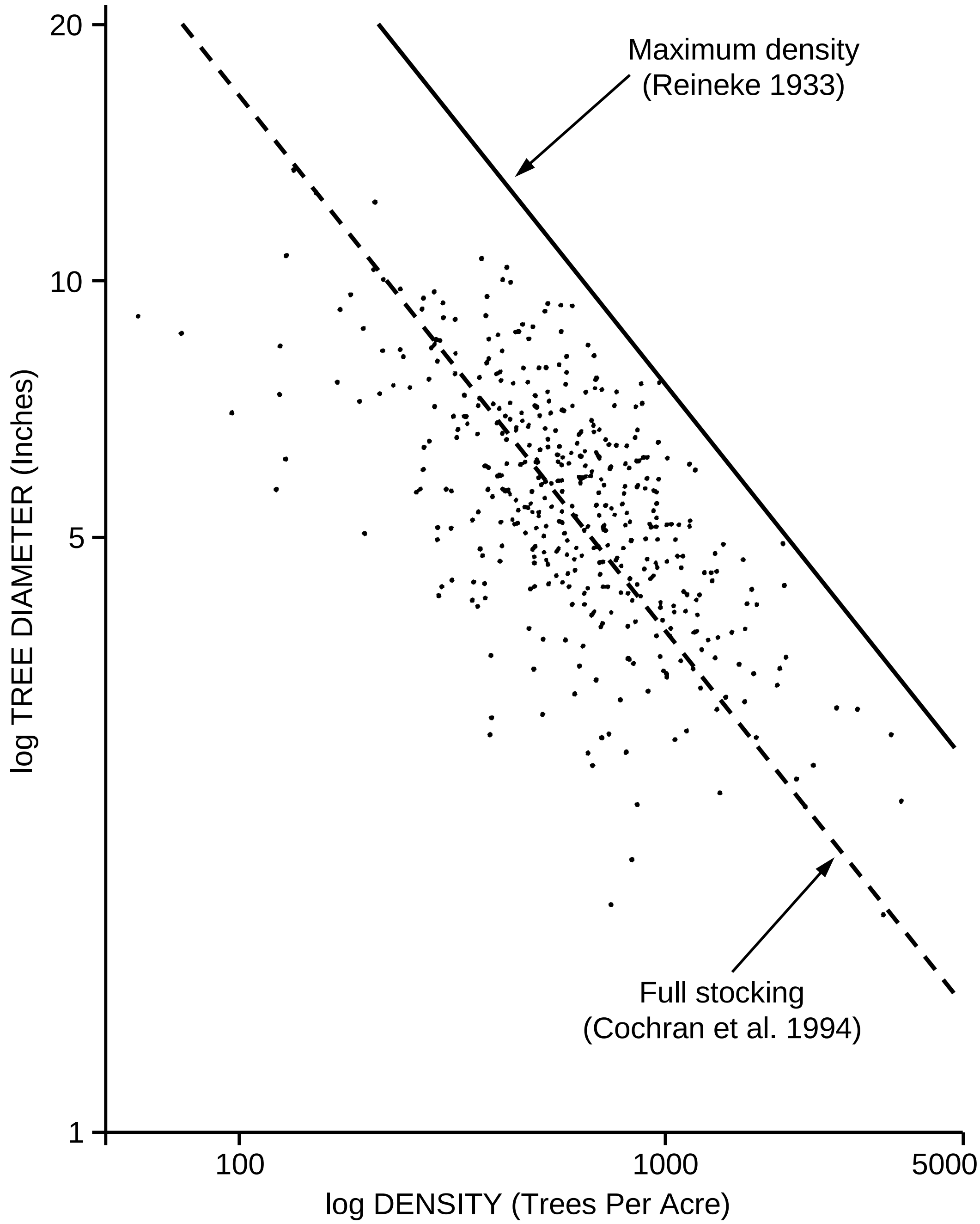

Figure 1 – Relationship between maximum density and full stocking. L.H. Reineke, creator of stand density index, plotted tree diameter and density for well-stocked, even-aged stands of a particular tree species on logarithmic scales (Reineke 1933). The result was a scatter plot where each dot represents one stand's data for mean diameter and trees per acre. Instead of following regular statistical methods (minimizing squared deviations), Reineke drew a straight line above the cloud of points (not through them). When a "least-squares" regression line is fitted to the scatter plot data, the result is average density for fully stocked stands. This average line is referred to as normal density or full stocking (Meyer 1961, McArdle et al. 1961); it represents an "average-maximum" level of competition. Cochran et al. (1994) used full stocking as a relative density reference level, which differs from Reineke's approach because he used maximum density as a reference level.

National stocking-guide policy stipulated that the reference level "be based on a standard of average maximum competition or no competition" (Ernst and Knapp 1985). Since full stocking is the same as normal density (fig. 1), and because normal density represents an average-maximum level of competition (Curtis 1970, MacLean 1979), the Cochran group selected full stocking as its reference level in accordance with the national policy.

Note: the national stocking-guide policy also established standards for how Forest Service Regions were supposed to format their stocking charts (e.g., in the "Gingrich format"). To my knowledge, this national policy is no longer followed. The Cochran note provided 13 Gringrich-style stocking charts (Cochran et al. 1994, figures 1-13), along with computer code to allow users to generate their own stocking charts (see appendix 2, pages 19-21, in the Cochran note).

After the Cochran note was published, I began receiving questions or concerns from managers about how the Cochran stocking recommendations could be implemented. Since the Cochran note lacks much of the detail that managers want – quantified values for the upper and lower limits of the management zone, basal area and trees per acre data, intertree spacing expressed in feet, and canopy cover percentages – it quickly became clear that the note provides a solid conceptual foundation but lacks the "nuts and bolts" needed by practitioners.

So in response to the questions and concerns, I developed an "implementation guide" to provide the information requested by stocking-level practitioners working on the Umatilla National Forest portion of the Blue Mountains. This implementation guide was published exactly five years after the Cochran note – in April of 1999.

The Cochran note describes full stocking in great detail, but it neither discusses nor quantifies maximum density. The implementation guide does not quantify maximum density explicitly, but it does provide the mathematical basis for how this stocking level could be calculated (see table 3 on page 15 in Powell 1999). Table 3 from Powell (1999), slightly modified for formatting purposes only, is provided below as table 1 for reference purposes.

Figure 2 shows five stocking levels and indexes them to maximum density as a reference level. The Cochran note, and Powell's follow-up implementation guide, express suggested stocking levels as some proportion of full stocking (table 1). In figure 2, the full stocking, ULMZ, and LLMZ terms relate directly to the Cochran note and the implementation guide. But the Cochran note used full stocking as a reference level, so the ULMZ and LLMZ stocking levels were indexed to full stocking, not to maximum density (i.e., in fig. 2, full stocking was at 100% instead of maximum density).

Table 1 below shows that information from Cochran et al. (1994) and the implementation guide (Powell 1999) is easily used to calculate maximum density.

1. Experience and professional judgment suggests that full stocking (normal density) is about 80% of maximum density, which means that maximum density can be calculated as 125% of full stocking (see table 1, above).

   This assumption is supported by other evidence, such as an analysis of red fir data showing that critical (near-maximum) density occurred at about 130% of normal density (Daniel et al. 1979, p. 319).

2. Both sources provide maximum, species-wide SDI values of full stocking for seven conifers in the Blue Mountains (see table 1 in Cochran et al. 1994, and table 2 in Powell 1999). Note that the province-wide data is used as a "cap" to prevent any calculated value for a plant association from exceeding the maximum value established for the Blue Mountains as a whole (and occasionally, calculated species values for certain plant associations did have to be reduced to the province-wide cap value). The province-wide data is reproduced here, as table 2, for reference purposes (adapted from Powell 1999). Note that the intercept values and slope factors in table 2 are used with Reineke's equation for calculating SDI (see equation 2 on page 3 in Cochran et al. 1994).

3. Both sources provide full stocking SDI values for combinations of plant association and tree species (see tables 3 and 4 in Cochran et al. 1994, and table 2 in Powell 1999).

4. SDI values for the full stocking level were used to calculate corresponding values of maximum density (full stocking SDI $\times$ 1.25 = maximum density SDI; see table 1 above).

Table 1: Characterization of selected stand development benchmarks or stocking level thresholds as percentages of maximum density and full stocking.

STAND DEVELOPMENT BENCHMARK OR STOCKING LEVEL THRESHOLD	PERCENT OF MAXIMUM DENSITY[1]	PERCENT OF FULL STOCKING[2]
Maximum density[3]	100%	125%
Full stocking (normal density)[4]	80%	100%
Lower limit of self-thinning zone[5]	60%	75%
Upper limit of the management zone	60%	75%
Crown ratio of 40 percent	50%	~63%
Lower limit of full site occupancy	35%	~45%
Lower limit of the management zone	~40%	50%
Onset of competition/crown closure	25%	~30%

[1] Percent of maximum density values are based on Long (1985), or were calculated.

[2] Percent of full stocking values are based on Cochran et al. (1994), or were calculated.

[3] Maximum density is the maximum stand density observed for a tree species; although rare in nature, it represents an upper limit (see fig. 1).

[4] Full stocking refers to normal stand density values as published in sources such as Meyer (1961); it has also been called average-maximum density (see fig. 1).

[5] The lower limit of self-thinning zone stocking threshold has also been referred to as the "zone of imminent competition mortality" (Drew and Flewelling 1979).

Note: Gray bands show thresholds that are considered to be identical or equivalent.

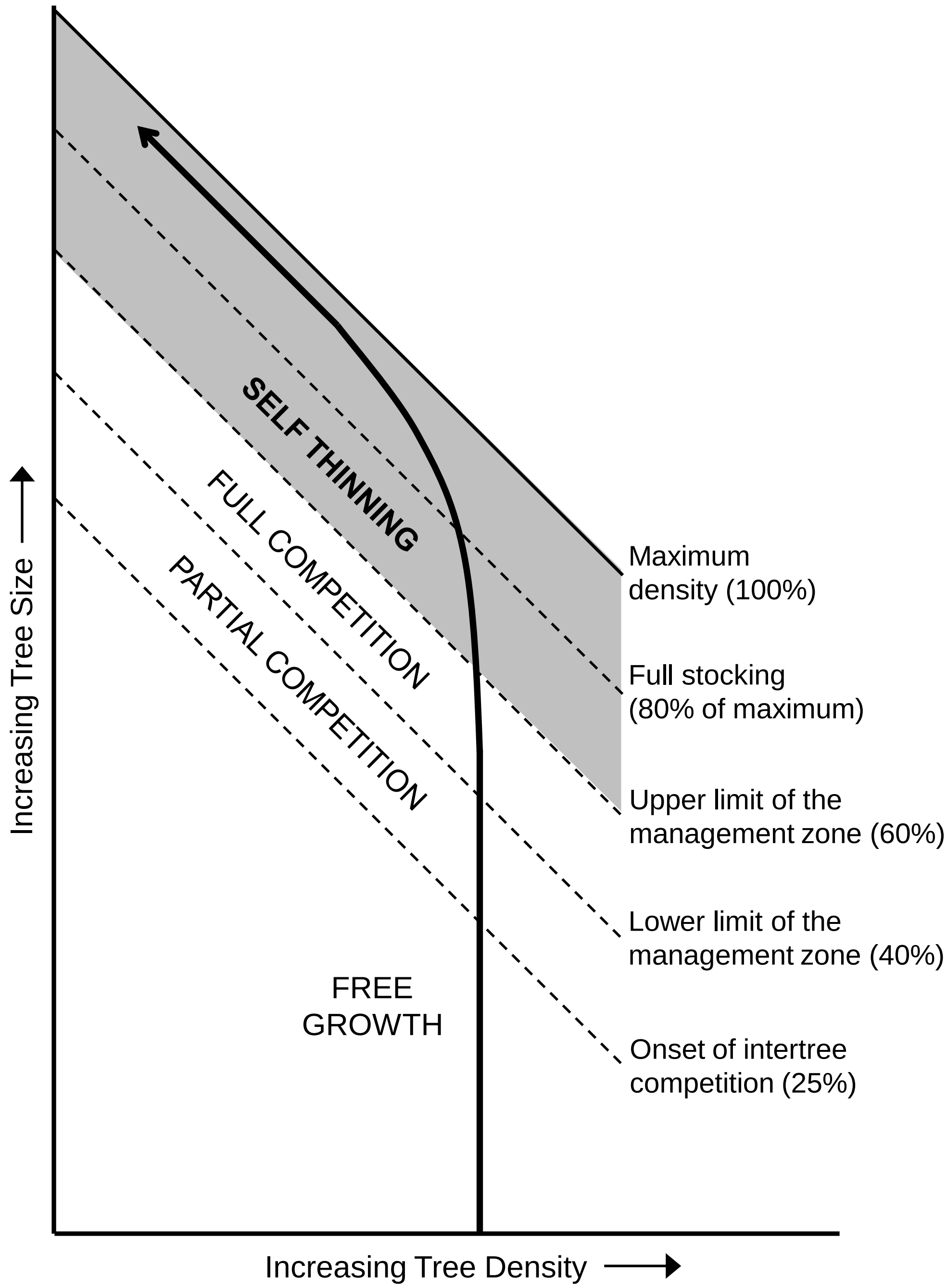

Figure 2 – Stand development indexed to maximum density. When Cochran et al. (1994) published suggested stocking levels for plant associations and tree species of northeastern Oregon and southeastern Washington, the levels were always expressed as some proportion of full stocking. This figure presents the stocking levels as a percentage of maximum density instead of full stocking. Note that full stocking, as used in the Cochran note, is the same as "normal density" because density information for fully-stocked natural stands was traditionally published in normal yield tables such as Barnes (1962), McArdle et al. (1961), and Meyer (1961). Although the names are different, full stocking and normal density are the same stocking level. The upper and lower limits of a management zone can be established by setting consistent percentages of full stocking or maximum density. The Cochran note did not use the "onset of intertree competition" threshold.

Table 2: Intercept values, slope factors, province-wide full stocking, and maximum density for tree species included in Cochran et al. (1994).

Tree Species	Intercept Value[1]	Slope Factor[1]	Province-Wide Full Stocking[1]	Maximum Density[2]
Ponderosa pine	9.97	1.77	365	456
Douglas-fir	9.42	1.51	380	475
Western larch	10.00	1.73	410	512
Lodgepole pine	9.63	1.74	277	346
Engelmann spruce	10.13	1.73	469	586
Grand fir	10.31	1.73	560	700
Subalpine fir	10.01	1.73	416	520

[1] Intercept values, slope factors, and full stocking values are taken from table 1 in Cochran et al. (1994). Because the full-stocking values are province wide for the Blue Mountains physiographic province of northeastern Oregon and southeastern Washington, they are not specific to any particular plant association.

[2] Maximum density was calculated as 125% of full stocking (see table 3). These values are also province wide for the Blue Mountains physiographic province of northeastern Oregon and southeastern Washington.

RESULTS FOR MAXIMUM STAND DENSITY INDEX

By using the analysis methodology described in the previous section, the Blue Mountains work group calculated new values of maximum SDI for many of the tree species and plant associations included in the Blue Mountains variant of the Forest Vegetation Simulator, and they are presented in table 3.

Note that there are three tree species (western white pine, mountain hemlock, and whitebark pine) for which no maximum SDI values are provided in table 3. These three species have a limited occurrence in the Blue Mountains, so they were seldom encountered during sampling for the plant association field guides and since growth basal area (GBA) data was not available for them, the Cochran process could not be used to convert GBA to SDI and then include their suggested stocking levels in Cochran et al. (1994).

Also note that table 3 includes many plant associations for which no maximum SDI values are provided. These are newer associations included in plant association field guides published after the Cochran note was released in April 1994. Newer associations are described in Crowe and Clausnitzer (1997) and Wells (2006) for riparian sites, and in Johnson (2004) and Johnson and Swanson (2005) for upland sites.

The new plant association field guides lack stockability information, so it would not be possible to use the Cochran methodology to develop suggested stocking levels for their forested plant associations. Table 3 includes every forested association for the Blue Mountains, and it clearly demonstrates how many of them lack detailed stocking data available as of December 2009! The Blue Mountains work group believes that one approach for addressing this lack of stocking information is to copy data from associations for which it is available to ecologically similar associations for which it is lacking, and we recommend that this approach be evaluated and if found to have merit, that it be implemented as soon as practicable.

BACKGROUND FOR SITE INDEX

Site index (SI) is defined as “a species-specific measure of actual or potential site quality, expressed in terms of the average height of trees included in a specified stand component” such as dominant and co-dominant trees (Helms 1998). SI is derived by measuring total height and age (either breast-height age, or total age) for “top-height” trees defined as the dominant and codominant crown classes in a stand, and then using the height and age measurements to calculate an SI value for each site tree.

By definition, SI provides the potential height of dominant and codominant trees, which are the tallest trees in an even-aged stand or the topmost layer in a multi-layered stand structure. This means that SI does not provide an estimate of average stand height because certain crown classes (intermediate and subordinate trees) are intentionally not sampled when selecting site trees.

If the site trees selected for measurement are chosen carefully, and if they meet the specifications of the published SI curves (such as lack of top damage from budworm or defoliating insects, little or no evidence of growth suppression in the increment core, etc.), then the SI values are assumed to provide an accurate assessment of inherent site quality.

SI values are expressed in feet – an SI value of 70 means that the total height for dominant and co-dominant trees at 50 years of age (if the site index curves use 50 as a base age) would average 70 feet. If the curves use 100 as a base age, then an SI value of 70 means that dominant and codominant trees would average 70 feet in total height at 100 years of age.

Site index values pertain to a base age (such as 50 years or 100 years), and base age varies from one set of published curves to another. Base age functions as an “indexing” mechanism because it scales all measurements to a common baseline, without which it would be difficult to know if top-height differences reflect site quality variation or the fact that a sampled stand had more time to grow (it was older) than another sampled stand.

The site index (SI) base age often varies between tree species, including whether the base age pertains to breast-height or total age (recent SI curves have tended to use breast-height age because it is easier to measure in the field). For the Blue Mountains, the published sources of SI curves are provided in table 4.

Table 3: Calculated values of maximum stand density index (Max) and site index (SI) for major tree species and plant associations of the Blue Mountains in northeastern Oregon and southeastern Washington.

Plant Association Code	Area	Ecoclass Code	FVS Eco	PP(10) Max	PP SI	DF(3) Max	DF SI	WL(2) Max	WL SI	LP(7) Max	LP SI	ES(8) Max	ES SI	GF(4) Max	GF SI	AF(9) Max	AF SI	WP(1) Max	WP SI	MH(5) Max	MH SI	WB Max	WB SI	Def Spp
ABLA2-PIAL/POPU	TFI	CAF0											51				26							
ABLA2-PIAL/POPH	TFI	CAF2									65													
ABLA2/CAGE	BO	CAG111	1				48		65	346	78		66			465	62							LP
ABLA2/STOC	BO	CAG4					56			346	78		64			465	48							LP
PSME/CAGE	BO	CDG111	2	278	77	351	52		59						62									PP
PSME/CARU	BO	CDG112	3	329	83	330	53		55						48									PP
PSME/CARU	WS	CDG121	4	451	86	475	55																	PP
PSME/bunchgrass	TFI	CDG3					43																	
PSME/HODI	BO	CDS611	5	425	86	319	64																	DF
PSME/SYAL	WS	CDS622	6	416	84	475	60																	PP
PSME/SYAL	BO	CDS624	8	341	81	309	61	256							70									DF
PSME/SYOR	WS	CDS623	7	451	90		55																	PP
PSME/SYOR	BO	CDS625			72		52																	
PSME/SPBE	WS	CDS634	9	441	82	464	61																	PP
PSME/PHMA	BO	CDS711	10	343	87	281	59	320	64															DF
PSME/PHMA	WS	CDS711		290	87	388	59		64															PP
PSME/ACGL-PHMA	WS	CDS722	11	351	96	346	64																	DF
PSME/VAME	BO	CDS821	12	241	92	229	53																	DF
PSME/VAME	WS	CDS812					60																	
PSME/CELE/CAGE	BO	CDSD			67		47																	
ABLA2/LIBO2	WS	CEF221	13					348	62	333	65	538	67			488	40							LP
ABLA2/STAM	WS	CEF311	14							346	65	586	69		57	443	65							LP
ABLA2/TRCA3	BO	CEF331	15							346	65	430	60			478								LP
ABLA2/POPU	WS	CEF411				475	59	513		346	65	568	58		54	483	54							LP
Unknown type (error?)	TFI	CEF9											55											
ABLA2/CARU	WS	CEG312					54		43		74		66		60		59							
PIEN/CAEU	COR	CEM111	16																					
PIEN/EQAR-STRO	COR	CEM221	17																					
PIEN/CLUN	COR	CEM222	18																					
PIEN/VAOC2-FORB	COR	CEM311	19																					
PIEN/VAOC2/CAEU	COR	CEM312	20																					
ABLA2/CLUN	WS	CES131	21	379				414	83			586	72	681	77	429	69							WL
ABLA2/MEFE	WS	CES221	22				56			346	65	460				410								LP
ABLA2/MEFE	BO	CES221					56									520								

Plant Association Code	Area	Ecoclass Code	FVS Eco	PP(10) Max	PP SI	DF(3) Max	DF SI	WL(2) Max	WL SI	LP(7) Max	LP SI	ES(8) Max	ES SI	GF(4) Max	GF SI	AF(9) Max	AF SI	WP(1) Max	WP SI	MH(5) Max	MH SI	WB Max	WB SI	Def Spp
ABLA2/VAME	BO	CES311	23					478	63	319		478	58		72	331	51							AF
ABLA2/CLUN	BO	CES314	24					513	79			586	69		69	520	53							WL
ABLA2/VAME	WS	CES315	25			475	55	460	62	346	82	573	65		55	425	63							LP
ABLA2/VASC	BO	CES411	26			458		475	46	346	66	458	53		61	456	44						19	LP
ABLA2/LIBO2	BO	CES414	27				64	513	58		66	474	60		52	419	53							AF
ABLA2/VASC/POPU	WS	CES415	28			475		513	51	346	70	568	57		51	483	48							LP
JUOC/FEID-AGSP	Both	CJG111			67		46																	
JUOC/ARTRV/FEID-AGSP	TFI	CJS2			61																			
JUOC/CELE	TFI	CJS4			58																			
PICO/LIBO2	WS	CLF211	29						55		72													
PICO/bunchgrass	TFI	CLG1									73		51		48		48							
PICO/rhizomatous grass	TFI	CLG2			82		53		55		68				49		44							
PICO/CARU-VASC	B73	CLG211	30																					
PICO/POPR	COR	CLM112	31																					
PICO/CAEU	COR	CLM113	32																					
PICO/CAAQ	COR	CLM114	33																					
PICO/VAOC2/CAEU	COR	CLM312	34																					
PICO/SPDO/FORB	COR	CLM313	35																					
PICO/SPDO/CAEU	COR	CLM314	36																					
PICO-PIEN/ELPA2	COR	CLM911	37																					
PICO/shrub, cool xeric	TFI	CLS4					51		55		65		50		46		44							
PICO/VASC	B73	CLS411	38																					
PICO/VASC/POPU	WS	CLS415	39						45		61		52				42							
PICO/CARU	BO	CLS416	40		78		53		55	279	66													
PICO(ABGR)/VAME-LIBO2	BO	CLS5		456		475	55	463	52	346	67	499	56	645	52	466								LP
PICO/VAME	B73	CLS511	41																					
PICO/VAME	WS	CLS515	42						46		65		46											
PICO(ABGR)/ALSI	BO	CLS6				475		513	59	346	65	586		700										LP
TSME/VASC	WS	CMS131	43							283	68	371				520					56			LP
TSME/VAME	WS	CMS231	44							283	68	371				520					58			
PIPO/bunchgrass	TFI	CPG1			47																			
PIPO/AGSP	BO	CPG111	45	166	72		52								69									PP
PIPO/FEID	BO	CPG112	46	243	74		59																	PP
PIPO/FEID	WS	CPG131	47	259	79		57																	PP
PIPO/AGSP	WS	CPG132	48	233	77		62																	PP
PIPO/CARU	BO	CPG221	49	456	77		55								66									PP
PIPO/CAGE	BO	CPG222	50	251	73		51				70													PP

Plant Association Code	Area	Ecoclass Code	FVS Eco	PP(10) Max	PP SI	DF(3) Max	DF SI	WL(2) Max	WL SI	LP(7) Max	LP SI	ES(8) Max	ES SI	GF(4) Max	GF SI	AF(9) Max	AF SI	WP(1) Max	WP SI	MH(5) Max	MH SI	WB Max	WB SI	Def Spp
PIPO/ELGL	B73	CPM111	51																					
PIPO/ARTRV	TFI	CPS1			76																			
PIPO/ARTRV/FEID-AGSP	BO	CPS131	52	238	73																			PP
PIPO/PUTR/CARO	BO	CPS221	53	304	74																			PP
PIPO/PUTR/CAGE	BO	CPS222	54	255	79																			PP
PIPO/PUTR/FEID-AGSP	BO	CPS226	55	231	64																			PP
PIPO/CELE/CAGE	BO	CPS232	56	290	65		53																	PP
PIPO/CELE/PONE	BO	CPS233	57	199	67																			PP
PIPO/CELE/FEID-AGSP	BO	CPS234	58	196	66		51																	PP
PIPO/SYAL-FLOODPLAIN	COR	CPS511	59																					
PIPO/SYAL	WS	CPS522	60	301	85		70																	PP
PIPO/SPBE	WS	CPS523	61	276	96		71																	PP
PIPO/SYAL	BO	CPS524	62	398	81		56																	PP
PIPO/SYOR	BO	CPS525	63	325	79																			PP
ABGR/TABR/CLUN	BO	CWC811	64									533	76	700	69									ES
ABGR/TABR/CLUN	WS	CWF422					73		82				76		78									
ABGR/TABR/LIBO2	BO	CWC812	65			475	76	378				374	66	700	90									ES
ABGR/LIBO2	WS	CWF311	66		104	475	60	511	60	346	73		59	700	59									LP
ABGR/LIBO2	BO	CWF312	67	456	92	475	62	463	58	346	72	499	53	645	56	466								LP
ABGR/CLUN	WS	CWF421	68	456	111	475	69	455	79	346	81	586	72	700	74				40					LP
ABGR/CLUN	BO	CWF421			111	475	69	513	79	346	81	586	72	700	74				40					LP
ABCO/CLUN	COR	CWF431	69																					
ABGR/TRCA3	BO	CWF512	70				75	498				485	72	693	79									ES
ABGR/GYDR	BO	CWF611	71											691	79									GF
ABGR/POMU-ASCA3	BO	CWF612	72					438	79			586		608	78									WL
ABGR/CARU-CAGE	TFI	CWG1			80		62						65		53									
ABGR/CAGE	BO	CWG111	73	263	81	376	56		64		70		68	700	50									PP
ABGR/CARU	WS	CWG112	74	456	90	475	60		55				75		56									PP
ABGR/CARU	BO	CWG113	75	395	80	446	56	384	59	346	76			555	52									PP
ABGR/BRVU	BO	CWG211	76					513	79			586		700	57		55							WL
ABGR/VAME	WS	CWS211	77	424	86	439	66	464	84	331	54	586	66	700	61									LP
ABGR/VAME	BO	CWS212	78	365	79	475	61	513	57	298	68	426	67	569	60	515								LP
ABGR/SPBE	WS	CWS321	79	456	92	475	58				74				65									PP
ABGR/SPBE	BO	CWS322	80	319	82	248	57				60			443	49									DF
ABGR/ACGL-PHMA	WS	CWS412	81		107	475	66	444	79					628	65									DF
ABGR/ACGL	BO	CWS541	82			301	70	439				405		576	71									DF
ABGR/VASC	BO	CWS811	83	215	101	343	59	380	61	346	65		43	460	48									LP

Plant Association Code	Area	Ecoclass Code	FVS Eco	PP(10) Max	PP SI	DF(3) Max	DF SI	WL(2) Max	WL SI	LP(7) Max	LP SI	ES(8) Max	ES SI	GF(4) Max	GF SI	AF(9) Max	AF SI	WP(1) Max	WP SI	MH(5) Max	MH SI	WB Max	WB SI	Def Spp
ABGR/VASC-LIBO2	BO	CWS812	84		81	434	56	316	56	346	75	436	70	618	56	230								WL
ABGR/ACGL	WS	CWS912	85	456		475	67		64					700	69									DF
POTR/ELGL	COR	HQM121	86																					
POTR-PICO/SPDO/CAEU	COR	HQM411	87																					
POTR/SYAL/ELGL	COR	HQS221	88																					
PIAL/ARAC2	GTR	CAF322																						
PIAL/LUAR3	GTR	CAF323																						
ABLA-PIAL/ARAC2	GTR	CAF324																						
PIAL/CAGE2	GTR	CAG131																						
ABLA-PIAL/JUPA-STLE2	GTR	CAG132																						
ABLA-PIAL/CAGE2	GTR	CAG133																						
PIAL/FEVI	GTR	CAG221																						
ABLA-PIAL/FEVI	GTR	CAG222																						
ABLA-PIAL/JUDR	GTR	CAG3																						
PIAL/VASC/LUHI4	GTR	CAS311																						
PIAL/VASC/ARCO9	GTR	CAS312																						
PIAL/VASC/ARAC2	GTR	CAS313																						
PIAL/JUCO6-ARNE	GTR	CAS422																						
ABLA-PIAL/JUCO6-ARNE	GTR	CAS423																						
ABLA-PIAL/JUCO6	GTR	CAS424																						
PIFL2/JUCO6	GTR	CAS511																						
PIAL/RIMO2/POPU3	GTR	CAS512																						
ABLA-PIAL/RIMO2/POPU3	GTR	CAS611																						
ABLA-PIAL/VASC/ARCO9	GTR	CAS621																						
ABLA-PIAL/VASC/CARO5	GTR	CAS622																						
ABLA-PIAL/VASC/ARAC2	GTR	CAS623																						
ABLA-PIAL/VASC-PHEM	GTR	CAS624																						
ABLA-PIAL/VASC/FEVI	GTR	CAS625																						
ABLA-PIAL/VASC/OREX	GTR	CAS626																						
ABLA-PIAL/VASC/LECOW2	GTR	CAS627																						
ABLA-PIAL/VASC-PHEM (AVALANCHE)	GTR	CAS628																						
ABLA-PIAL/VASC/FEVI (AV-ALANCHE)	GTR	CAS629																						
PSME/TRCA	GTR	CDF313																						
PSME-PIPO-JUOC/FEID	GTR	CDG333																						
PSME/SYAL (FLOODPLAIN)	GTR	CDS628																						

Plant Association Code	Area	Ecoclass Code	FVS Eco	PP(10) Max	PP SI	DF(3) Max	DF SI	WL(2) Max	WL SI	LP(7) Max	LP SI	ES(8) Max	ES SI	GF(4) Max	GF SI	AF(9) Max	AF SI	WP(1) Max	WP SI	MH(5) Max	MH SI	WB Max	WB SI	Def Spp
PSME/SYOR2/CAGE2	GTR	CDS642																						
PSME/ARNE/CAGE2	GTR	CDS664																						
PSME/ACGL-PHMA5 (FLOODPLAIN)	GTR	CDS724																						
PSME/ACGL-SYOR2	GTR	CDS725																						
PSME/RIMO2/POPU3	GTR	CDS911																						
ABLA/XETE	GTR	CEF111																						
ABLA-PIEN/LIBO3	GTR	CEF2																						
ABLA/ATFI	GTR	CEF332																						
ABLA/SETR	GTR	CEF333																						
PIEN/ATFI	GTR	CEF334																						
PIEN/SETR	GTR	CEF335																						
ABLA-PIEN/SETR	GTR	CEF336																						
ABLA/ARCO9	GTR	CEF412																						
ABLA-PIEN/TRCA	GTR	CEF425																						
ABLA-PIEN/POPU3	GTR	CEF426																						
ABLA/ARCO9	GTR	CEF435																						
ABLA-PIEN/ARCO9	GTR	CEF436																						
ABLA-PIEN/CLUN2	GTR	CEF437																						
ABLA/POPH	GTR	CEF511																						
ABLA-PIEN/LUHI4	GTR	CEG131																						
PIEN-ABLA/CASC12	GTR	CEG201																						
ABLA/STOC2	GTR	CEG323																						
ABLA/FEVI	GTR	CEG411																						
ABLA/JUDR	GTR	CEG412																						
ABLA/JUTE	GTR	CEG413																						
ABLA/JUPA (AVALANCHE)	GTR	CEG414																						
PIEN/CADI6	GTR	CEM121																						
ABLA/CADI6	GTR	CEM122																						
ABLA/CAAQ	GTR	CEM123																						
ABLA/CACA4	GTR	CEM124																						
PIEN/BRVU	GTR	CEM125																						
PIEN/CILA2	GTR	CEM126																						
PIEN-ABLA/SETR	GTR	CEM201																						
PIEN/EQAR	GTR	CEM211																						
ABLA/VAUL/CASC12	GTR	CEM313																						
ABLA-PIEN/MEFE	GTR	CES2																						

Plant Association Code	Area	Ecoclass Code	FVS Eco	PP(10) Max	PP SI	DF(3) Max	DF SI	WL(2) Max	WL SI	LP(7) Max	LP SI	ES(8) Max	ES SI	GF(4) Max	GF SI	AF(9) Max	AF SI	WP(1) Max	WP SI	MH(5) Max	MH SI	WB Max	WB SI	Def Spp
ABLA/RHAL2	GTR	CES214																						
ABLA-PIEN/RHAL2	GTR	CES215																						
ABLA/VAME (FLOODPLAIN)	GTR	CES316																						
ABLA-PIEN/VASC-PHEM	GTR	CES427																						
ABLA/VASC-PHEM	GTR	CES428																						
ABLA/ARNE/ARAC2	GTR	CES429																						
PIEN/COST4	GTR	CES511																						
ABLA-PIEN/LEGL (FLOOD-PLAIN)	GTR	CES610																						
ABLA-PIEN/LEGL	GTR	CES612																						
ABLA-PIEN/MEFE (FLOOD-PLAIN)	GTR	CES710																						
ABLA-PIMO3/CHUM	GTR	CES8																						
JUOC/AGSP	GTR	CJG113																						
JUOC/ARAR8	GTR	CJS1																						
JUOC/ARAR8/FEID	GTR	CJS112																						
JUOC/PUTR2/FEID-AGSP	GTR	CJS321																						
JUOC/CELE3/FEID-AGSP	GTR	CJS41																						
JUOC/CELE3/CAGE2	GTR	CJS42																						
JUSC2/CELE3	GTR	CJS5																						
JUOC/ARRI2	GTR	CJS8																						
JUOC/ARRI2 (SCAB)	GTR	CJS811																						
PICO(ABLA)/STOC2	GTR	CLG11																						
PICO(ABGR)/CARU	GTR	CLG21																						
PICO(ABLA)/CAGE2	GTR	CLG322																						
PICO/DECE	GTR	CLM115																						
PICO/CALA30	GTR	CLM116																						
PICO/CACA4	GTR	CLM117																						
PICO/CASC12	GTR	CLM118																						
PICO/ALIN2/MESIC FORB	GTR	CLM511																						
PICO(ABGR)/VASC/CARU	GTR	CLS417																						
PICO(ABLA)/VASC	GTR	CLS418																						
PICO(ABGR)/VAME/CARU	GTR	CLS512																						
PICO(ABGR)/VAME	GTR	CLS513																						
PICO(ABLA)/VAME	GTR	CLS514																						
PICO(ABLA)/VAME/CARU	GTR	CLS516																						
PICO(ABGR)/VAME/PTAQ	GTR	CLS519																						

Plant Association Code	Area	Ecoclass Code	FVS Eco	PP(10) Max	PP SI	DF(3) Max	DF SI	WL(2) Max	WL SI	LP(7) Max	LP SI	ES(8) Max	ES SI	GF(4) Max	GF SI	AF(9) Max	AF SI	WP(1) Max	WP SI	MH(5) Max	MH SI	WB Max	WB SI	Def Spp
PICO(ABGR)/ARNE	GTR	CLS57																						
PICO(ABGR)/ALSI3	GTR	CLS58																						
PIPO-JUOC/CELE3-SYOR2	GTR	CPC212																						
PIPO/POPR	GTR	CPM112																						
PIPO/ARTRV/CAGE2	GTR	CPS132																						
PIPO/PUTR2/AGSP-POSA12	GTR	CPS229																						
PIPO/PUTR2/AGSP	GTR	CPS231																						
PIPO/ARAR8	GTR	CPS61																						
PIPO/CRDO2	GTR	CPS722																						
PIPO/PERA4	GTR	CPS8																						
PIPO/RHGL	GTR	CPS9																						
PIMO3/DECE	GTR	CQM111																						
ABGR/TABR2/LIBO3 (FLOODPLAIN)	GTR	CWF424																						
ABGR/ARCO9	GTR	CWF444																						
ABGR/COOC	GTR	CWF511																						
ABGR/ATFI	GTR	CWF613																						
ABGR/CALA30	GTR	CWM311																						
ABGR-CHNO/VAME	GTR	CWS232																						
ABGR/SYAL (FLOODPLAIN)	GTR	CWS314																						
ABGR/CRDO2/CADE9	GTR	CWS423																						
ABGR/ACGL (FLOODPLAIN)	GTR	CWS543																						
POTR15/SALA5	GTR	HCS112																						
POTR15/ALIN2-COST4	GTR	HCS113																						
POTR15/ACGL	GTR	HCS114																						
POTR15/SYAL	GTR	HCS312																						
POTR5/CAGE2	GTR	HQG112																						
POTR5/POPR	GTR	HQM122																						
POTR5/CACA4	GTR	HQM123																						
POTR5/CALA30	GTR	HQM211																						
POTR5/CAAQ	GTR	HQM212																						
POTR5/MESIC FORB	GTR	HQM511																						
POTR5/ALIN2-COST4	GTR	HQS222																						
POTR5/ALIN2-SYAL	GTR	HQS223																						
POTR5-PIEN/GLST-CACA4	IP	HQC113																						
POTR5/CRDO2	IP	HQS4																						
POTR5/CAFL4	IP	HQG113																						

Plant Association Code	Area	Ecoclass Code	FVS Eco	PP(10) Max	PP SI	DF(3) Max	DF SI	WL(2) Max	WL SI	LP(7) Max	LP SI	ES(8) Max	ES SI	GF(4) Max	GF SI	AF(9) Max	AF SI	WP(1) Max	WP SI	MH(5) Max	MH SI	WB Max	WB SI	Def Spp
POTR5/ALPR3	IP	HQM611																						
POTR5 (RUBBLE, HIGH)	IP	HQR101																						
POTR5 (RUBBLE, LOW)	IP	HQR102																						
POTR5(ABLA)/RUOC2	IP	HQC114																						
POTR5(ABGR)/HODI	IP	HQC115																						
POTR5(ABGR)/SYMPH	IP	HQC116																						
POTR5/PRVI	IP	HQS5																						
POTR5(PSME)/PREM	IP	HQC117																						
POTR5(PIPO-PSME)/SYMPH	IP	HQC118																						
POTR5/CARU	IP	HQG114																						
POTR5/EXOTIC GRASS	IP	HQC115																						

Sources/Notes: Plant association and ecoclass codes are used to record potential vegetation types (plant associations, plant community types, plant communities) on field forms and in computer databases; both codes are taken primarily from Powell et al. (2007). The Area column shows the source of plant association and ecoclass codes for the potential vegetation type: B73 is Blue Mountain plant communities (Hall 1973), BO is Blue-Ochoco (Johnson and Clausnitzer 1992), Both refers to types included in both the BO and WS sources and yet the same ecoclass code was used for the type in both guides, COR is central Oregon riparian (Kovalchik 1987), GTR is used for types included in Powell et al. (2007) and not covered by another Area source (these are primarily riparian or nonforest types from Crowe and Clausnitzer 1997, Johnson and Swanson 2005, and Wells 2006), IP refers to "In Press" types from a pending classification of quaking aspen communities, TFI refers to types established for the Tri-Forest Inventory program and documented in Hall (1998), and WS is Wallowa-Snake (Johnson and Simon 1987). FVS Eco provides the 2-digit numeric code used by FVS to denote habitat types or plant associations. Species columns (PP, DF, WL, LP, ES, GF, AF, WP, MH, WB) show calculated values of maximum stand density index (Max) and site index (SI); maximum SDI values are based on Cochran et al. (1994) and Powell (1999), whereas site index values are based on measured values of height and age from 6,509 site trees selected during establishment of the occasion 1 Current Vegetation Survey plots across all three Blue Mountains national forests from 1993-1996. Site Index (SI) is calculated using an equation referencing tree age and tree height as input variables. Site trees were pooled (all 3 Blue Mountain national forests combined) and then stratified by potential vegetation type (ecoclass). Species code (PP) and the number after a species code (10) refers to the FVS species identifier and sequence number, respectively. For plant communities or plant community types, which are seral stages of a plant association, the maximum SDI and site index values, by species, from the parent plant association were used (an example: CAG4 is derived from CAG111, so the max SDI and SI values from CAG111 were used for CAG4). Default species (Def Spp) is the recommended species to use for the potential vegetation type, as determined by the Blue Mountains working group that compiled this table. Note that the information in this table was developed by a Blue Mountains working group, consisting of Bruce Countryman, Don Justice, Dave Powell, Mike Tatum, and Ed Uebler, during a series of meetings between 2007 and 2009.

Table 4: Source of site index curves for major tree species of the Blue Mountains.

Tree Species	Species Code	Site Index Source	Base Age (Years)	Age Limit (Years)
Engelmann spruce	PIEN	Brickell 1970	50 (total)	≤ 200
Grand fir	ABGR	Cochran 1979b	50 (BH)	≤ 100
Interior Douglas-fir	PSME	Cochran 1979a	50 (BH)	≤ 100
Lodgepole pine	PICO	Dahms 1975	90 (BH)	≤ 120
Mountain hemlock	TSME	Means et al. 1986	100 (BH)	≤ 240
Ponderosa pine	PIPO	Barrett 1978	100 (BH)	≤ 140
Subalpine fir	ABLA2	Brickell 1970	50 (total)	≤ 200
Western larch	LAOC	Cochran 1985	50 (BH)	≤ 100
Western white pine	PIMO	Brickell 1970	50 (total)	≤ 105
Whitebark pine	PIAL	Hegyi et al. 1981	100 (total)	≤ 300

Sources/Notes: Species code is an alphanumeric code used for species identification in the CVS database; "BH" in the base age column indicates that the base age pertains to a breast-height age rather than a total age; the age limit is the age range of measured site trees for which the site index curve is applicable (trees beyond this age range are not preferred site trees according to the published specifications for the site index curves).

CVS PLOTS AS A DATA SOURCE FOR SITE INDEX

In the 1990s, the Blue Mountain national forests installed a grid-based inventory system called the Current Vegetation Survey (CVS) (USDA Forest Service 1995). CVS plots were installed on a 1.7-mile grid (each plot was located 1.7 miles away from adjoining plots) except for designated Wilderness areas, where the grid spacing was 3.4 miles between plots.

For the Blue Mountains national forests of northeastern Oregon, southeastern Washington and west-central Idaho, the initial installation of forested CVS plots occurred in 1993 and 1994; nonforest CVS plots were established across all three national forests in 1995 and 1996. Plot information collected during this 1993-1996 period is referred to as occasion 1 data. Since their initial installation, every CVS plot has been remeasured once and this subsequent information is referred to as occasion 2 data (Christensen et al. 2007).

When considering data sources providing measured values for a wide range of tree attributes, the CVS information is generally acknowledged to be the best dataset available for the Blue Mountains because its grid-based approach prevents plot location bias, and because its quality control/quality assurance emphasis was very high (Max et al. 1996). For this reason, it was decided to use the CVS information when developing updated values of site index for the Blue Mountains variant of FVS.

ANALYSIS METHODOLOGY FOR SITE INDEX

The occasion 1 CVS data for all three Blue Mountains national forests was pooled, and the resulting database was queried to extract the site tree records and their associated information, including the plots and points they occurred on. Site trees were easily identified in the database because they have a unique vegetation (tree history) code: 13.

Potential vegetation is represented in the CVS database using ecoclass codes. Each CVS plot consists of a 5-point cluster, and an ecoclass code was recorded for each of the five points. Site trees are coded to the point they occur on or near, so an ecoclass code was readily assigned to each site tree record by using a database query and the CVS plot and point identifiers as common fields between the ecoclass and site index tables.

After 6,664 site tree records were extracted from the CVS occasion 1 database (these were all records with a vegetation code of 13), the data was filtered to remove problem records. These records were missing a measured height or age value, which means that site index could not be calculated, or the measured age value exceeded the age limit established for the curve (see final column in table 4).

Certain site index curves, such as Cochran's curve for western larch (Cochran 1985), are very sensitive to the age limit and age values beyond the limit quickly produce nonsensical results. A total of 155 problem records were removed from the dataset, resulting in 6,509 records being usable for further analysis.

The analysis dataset was then transferred to Excel and stratified by potential vegetation type (plant association) by using the ecoclass code associated with each record. Site index was calculated for each record by using an equation referencing the measured values of tree age and tree height as input variables. The source of calculation equations varied – most came from the published site index source document (see table 4), whereas others came from USDA Forest Service (1987) or Hanson et al. (2002).

RESULTS FOR SITE INDEX

By using the analysis methodology described in the previous section, the Blue Mountains work group calculated new values of site index for many of the potential vegetation types (plant associations primarily, but also consisting of plant communities and plant community types) included in the Blue Mountains variant of the Forest Vegetation Simulator. The new site index values are presented in tables 3 and 5.

Close inspection of table 3 reveals that for any particular plant association code (column 1), site index information was available for some species and not for others. And in many instances, a new value of site index was available for a tree species and yet a new value of maximum SDI was not. In a few cases, the opposite situation occurred – an updated value of maximum SDI was available for a species and yet a new value of site index was not. This pattern demonstrates that the SDI and site index updates are not linked – and this result is not surprising because each update item was based on a different data source.

Table 5 also provides the number of site tree records available for an ecoclass-species combination (the Tree Count column), along with minimum, maximum, and mean values of site index (the mean value is the final column labeled Site Index (Feet)).

Table 5: Summary of site index information for plant associations of the Blue Mountains in northeastern Oregon and southeastern Washington.

Ecoclass	Tree Species	Tree Count	Min Value	Max Value	Site Index (Feet)
CAF0	ABLA2	3	17.3	36.2	25.9
	PIEN	6	34.8	72.7	51.4
CAF2	PICO	3	53.0	73.8	64.9
CAG111	ABLA2	4	41.6	77.1	61.5
	LAOC	4	44.6	78.5	64.9
	PIEN	6	55.2	72.6	66.3
	PSME	5	26.6	65.6	48.3
CAG4	ABLA2	10	32.5	65.9	47.7
	PICO	3	73.7	80.3	77.8
	PIEN	3	59.5	66.8	64.1
	PSME	3	48.9	62.7	55.7
CDG111	ABGR	5	41.9	97.4	62.3
	LAOC	6	46.6	74.4	59.1
	PIPO	121	41.7	127.3	76.7
	PSME	276	17.8	88.8	51.6
CDG112	ABGR	5	34.7	62.6	47.9
	LAOC	5	50.2	61.1	55.1
	PIPO	94	47.9	122.3	82.8
	PSME	160	26.5	78.0	53.0
CDG121	PIPO	19	53.9	120.4	85.7
	PSME	89	19.4	100.8	55.0
CDG3	PSME	4	35.0	58.8	43.2
CDS611	PIPO	7	70.8	110.1	86.1
	PSME	28	47.6	86.3	63.8
CDS622	PIPO	10	62.3	107.4	84.0
	PSME	64	32.9	88.3	60.2
CDS623	PIPO	5	77.2	100.5	90.0
	PSME	28	34.3	75.6	55.3
CDS624	ABGR	6	52.7	97.8	70.3
	PIPO	33	49.2	112.0	81.0
	PSME	125	35.7	94.9	61.3
CDS625	PIPO	10	57.4	105.9	71.7
	PSME	23	32.8	70.0	51.7
CDS634	PIPO	19	53.1	109.0	82.1
	PSME	81	33.3	88.4	60.5
CDS711	LAOC	3	53.4	72.7	64.3
	PIPO	44	58.1	121.8	86.9
	PSME	183	23.0	103.8	58.9

Ecoclass	Tree Species	Tree Count	Min Value	Max Value	Site Index (Feet)
CDS722	PIPO	8	76.6	141.1	96.1
	PSME	120	38.1	96.7	64.3
CDS812	PSME	4	54.3	64.2	59.7
CDS821	PIPO	5	85.3	105.6	92.3
	PSME	9	47.4	59.4	53.3
CDSD	PIPO	16	48.9	87.7	66.5
	PSME	49	28.4	78.9	47.3
CEF221	ABLA2	9	21.7	55.2	40.4
	LAOC	1	61.7	61.7	61.7
	PIEN	11	38.4	80.2	66.8
CEF311	ABGR	3	24.5	76.5	56.6
	ABLA2	3	50.1	76.8	64.6
	PIEN	6	57.3	84.9	69.1
CEF331	PIEN	8	38.5	75.5	59.8
CEF411	ABGR	5	39.1	86.8	54.4
	ABLA2	41	24.4	80.9	53.8
	PICO	9	54.7	78.1	65.4
	PIEN	14	37.0	86.3	57.8
	PSME	16	45.5	68.4	59.1
CEF9	PIEN	3	49.9	65.4	55.2
CEG312	ABGR	3	34.7	74.3	59.8
	ABLA2	5	25.1	73.1	58.8
	LAOC	2	38.3	46.9	42.6
	PICO	3	64.8	85.3	73.9
	PIEN	2	60.4	71.3	65.9
	PSME	7	44.4	66.6	53.5
CES131	ABGR	9	62.4	94.2	77.1
	ABLA2	7	53.1	84.9	68.5
	LAOC	3	74.9	89.7	83.3
	PIEN	34	44.6	97.4	72.3
CES221	PSME	2	51.1	61.1	56.1
CES311	ABGR	7	37.3	135.2	71.6
	ABLA2	6	37.5	74.1	50.5
	LAOC	1	62.9	62.9	62.9
	PIEN	12	40.6	83.9	58.0
CES314	ABGR	4	43.2	114.6	69.1
	ABLA2	5	35.3	81.9	53.2
	LAOC	3	70.8	84.8	79.2
	PIEN	26	47.3	87.2	68.7
CES315	ABGR	17	22.4	94.0	55.0
	ABLA2	7	57.3	67.8	63.1

Ecoclass	Tree Species	Tree Count	Min Value	Max Value	Site Index (Feet)
	LAOC	9	31.5	84.6	62.4
	PICO	8	71.4	94.9	82.2
	PIEN	37	26.7	91.9	65.1
	PSME	4	51.7	59.7	55.4
CES411	ABGR	4	44.4	90.6	60.9
	ABLA2	12	18.6	65.7	43.6
	LAOC	5	21.6	66.7	45.8
	PIAL	2	16.3	21.4	18.9
	PICO	17	48.5	87.7	65.8
	PIEN	39	20.5	71.2	52.5
CES414	ABGR	5	42.9	59.3	51.5
	ABLA2	4	31.1	64.7	52.8
	LAOC	10	37.0	84.3	58.2
	PICO	6	50.2	77.9	65.6
	PIEN	38	23.6	88.9	59.5
	PSME	4	58.0	70.0	63.9
CES415	ABGR	9	19.8	75.7	51.0
	ABLA2	19	22.1	66.8	48.3
	LAOC	2	44.1	58.2	51.2
	PICO	5	55.1	78.3	69.9
	PIEN	13	33.5	78.0	56.8
CJG111	PIPO	21	46.8	98.6	66.9
	PSME	6	37.2	50.4	45.5
CJS2	PIPO	3	54.2	69.9	61.2
CJS4	PIPO	9	35.4	74.6	58.1
CLF211	LAOC	9	37.5	73.9	55.4
	PICO	5	63.3	84.5	71.6
CLG1	ABGR	2	45.9	51.0	48.4
	ABLA2	2	44.9	51.8	48.4
	PICO	3	66.4	81.9	72.9
	PIEN	2	43.4	58.6	51.0
CLG2	ABGR	40	15.2	92.5	49.4
	ABLA2	3	43.3	44.9	44.1
	LAOC	11	29.9	73.5	55.2
	PICO	23	53.8	83.2	68.4
	PIPO	23	48.4	101.4	82.0
	PSME	23	29.8	78.4	53.0
CLS4	ABGR	27	25.8	59.7	46.3
	ABLA2	15	25.9	59.6	44.4
	LAOC	5	28.1	69.0	55.1
	PICO	25	42.9	81.7	64.5

Ecoclass	Tree Species	Tree Count	Min Value	Max Value	Site Index (Feet)
	PIEN	20	20.4	77.8	49.8
	PSME	6	31.1	69.7	50.8
CLS415	ABLA2	2	39.5	43.5	41.5
	LAOC	6	35.6	51.7	45.3
	PICO	8	42.4	85.3	60.8
	PIEN	4	46.0	56.5	52.4
CLS416	LAOC	7	32.7	74.0	55.4
	PICO	39	33.7	91.7	65.9
	PIPO	20	50.3	96.8	77.8
	PSME	2	47.0	59.2	53.1
CLS5	ABGR	27	25.9	153.3	51.6
	LAOC	33	25.0	76.7	52.0
	PICO	7	47.1	81.9	66.5
	PIEN	4	44.4	67.2	56.1
	PSME	10	47.9	70.2	55.4
CLS515	LAOC	5	33.0	58.6	45.7
	PICO	2	63.5	65.6	64.6
	PIEN	3	41.4	49.0	46.3
CLS6	LAOC	3	54.3	61.8	58.7
CMS131	PICO	4	64.1	71.8	67.7
	TSME	3	53.3	61.3	56.4
CMS231	TSME	5	52.2	78.1	57.9
CPG1	PIPO	2	45.6	47.5	46.6
CPG111	ABGR	3	38.1	94.2	68.7
	PIPO	301	34.9	119.8	71.7
	PSME	13	40.9	64.6	52.3
CPG112	PIPO	71	40.4	119.3	74.3
	PSME	3	40.0	76.1	58.7
CPG131	PIPO	49	45.0	108.8	79.0
	PSME	6	45.1	63.3	56.7
CPG132	PIPO	20	51.2	108.3	76.6
	PSME	2	54.7	68.3	61.5
CPG221	ABGR	6	40.7	129.2	66.0
	PIPO	133	41.3	151.2	77.3
	PSME	4	51.1	59.1	55.0
CPG222	PICO	3	56.5	77.6	69.9
	PIPO	243	36.8	133.0	72.7
	PSME	11	41.3	59.0	50.9
CPS1	PIPO	6	62.0	90.1	75.7
CPS131	PIPO	27	42.5	94.4	72.7
CPS221	PIPO	6	48.0	92.2	74.2

Ecoclass	Tree Species	Tree Count	Min Value	Max Value	Site Index (Feet)
CPS222	PIPO	9	42.5	102.3	78.8
CPS226	PIPO	11	47.1	85.8	64.3
CPS232	PIPO	38	34.2	89.3	65.4
	PSME	2	47.9	57.1	52.5
CPS233	PIPO	8	51.5	88.6	66.9
CPS234	PIPO	30	36.3	94.6	66.3
	PSME	3	47.1	55.3	51.0
CPS522	PIPO	27	47.7	113.2	85.0
	PSME	3	60.5	74.9	69.5
CPS523	PIPO	29	57.6	124.3	95.7
	PSME	3	60.8	89.2	71.1
CPS524	PIPO	120	38.6	128.7	80.5
	PSME	8	37.0	73.7	56.3
CPS525	PIPO	23	51.7	109.8	78.7
CWC811	ABGR	4	62.5	78.5	69.3
CWC812	ABGR	8	35.8	165.1	89.5
	PIEN	2	63.3	68.0	65.7
	PSME	3	58.9	89.9	75.7
CWF311	ABGR	44	26.1	90.5	58.6
	LAOC	6	49.4	65.7	59.5
	PICO	2	72.8	73.2	73.0
	PIEN	3	56.3	63.0	58.9
	PIPO	3	88.0	112.6	103.6
	PSME	23	48.7	76.2	59.8
CWF312	ABGR	80	13.4	122.8	56.1
	LAOC	30	32.8	93.8	58.0
	PICO	7	56.7	85.1	72.4
	PIEN	22	26.1	68.0	53.4
	PIPO	8	54.7	108.0	92.1
	PSME	38	47.0	76.5	61.8
CWF421	ABGR	112	17.6	153.2	74.0
	LAOC	15	54.3	105.6	78.5
	PICO	5	68.2	104.0	80.8
	PIEN	24	39.4	100.9	72.2
	PIMO	2	29.6	49.6	39.6
	PIPO	4	94.9	125.5	111.4
	PSME	28	50.9	82.4	69.4
CWF422	ABGR	27	41.3	164.8	77.8
	LAOC	3	76.8	84.7	81.6
	PIEN	6	64.6	97.4	75.9
	PSME	11	46.9	96.6	73.3

Ecoclass	Tree Species	Tree Count	Min Value	Max Value	Site Index (Feet)
CWF512	ABGR	8	55.6	106.8	79.4
	PSME	4	68.0	81.4	74.9
CWF612	ABGR	5	48.1	103.4	77.8
CWG1	ABGR	26	29.7	84.0	52.6
	PIEN	2	62.2	67.2	64.7
	PIPO	4	69.7	91.6	80.0
	PSME	15	40.5	87.1	61.9
CWG111	ABGR	259	14.2	101.0	49.7
	LAOC	25	42.0	93.3	63.9
	PICO	19	32.5	95.3	69.5
	PIEN	5	48.6	91.8	67.8
	PIPO	66	45.1	112.9	81.3
	PSME	100	25.0	83.6	55.5
CWG112	ABGR	97	20.9	91.9	56.1
	LAOC	2	39.9	69.6	54.8
	PIEN	3	58.9	91.6	74.9
	PIPO	20	65.3	108.2	89.9
	PSME	58	32.1	85.3	60.1
CWG113	ABGR	302	14.0	166.8	51.5
	LAOC	33	21.6	90.4	59.1
	PICO	2	75.6	75.7	75.7
	PIPO	81	42.6	111.3	80.3
	PSME	99	30.6	97.6	56.1
CWG211	ABGR	5	29.2	73.1	57.0
	ABLA2	2	52.4	56.9	54.7
CWS211	ABGR	89	20.9	105.4	60.5
	LAOC	2	64.3	104.0	84.2
	PICO	2	42.7	64.5	53.6
	PIEN	8	54.6	80.5	66.0
	PIPO	3	82.5	90.0	86.4
	PSME	28	35.5	79.1	65.8
CWS212	ABGR	46	10.3	139.7	59.5
	LAOC	22	17.5	93.0	57.1
	PICO	5	53.9	76.0	67.8
	PIEN	6	46.3	84.4	67.4
	PIPO	8	23.2	94.3	79.2
	PSME	22	47.6	73.4	60.8
CWS321	ABGR	31	26.9	97.4	64.5
	PICO	2	71.4	76.7	74.1
	PIPO	12	80.6	115.5	91.5
	PSME	11	47.6	74.1	57.9

Ecoclass	Tree Species	Tree Count	Min Value	Max Value	Site Index (Feet)
CWS322	ABGR	32	19.5	81.1	49.1
	PICO	2	56.7	63.8	60.3
	PIPO	9	64.3	100.3	82.2
	PSME	23	42.7	84.2	57.2
CWS412	ABGR	45	34.6	102.9	64.6
	LAOC	1	78.5	78.5	78.5
	PIPO	3	98.8	116.9	107.4
	PSME	44	47.0	97.0	66.2
CWS541	ABGR	39	36.0	124.1	71.2
	PSME	16	53.3	89.6	69.8
CWS811	ABGR	68	12.8	115.3	47.6
	LAOC	30	29.4	90.9	60.9
	PICO	33	43.2	89.8	65.2
	PIEN	3	36.0	48.3	43.1
	PIPO	5	70.9	148.8	100.8
	PSME	20	41.9	76.3	59.3
CWS812	ABGR	28	24.1	106.8	56.4
	LAOC	22	26.9	74.5	55.5
	PICO	12	50.8	90.7	74.7
	PIEN	6	65.0	78.8	70.4
	PIPO	2	80.7	81.3	81.0
	PSME	15	43.7	69.0	55.9
CWS912	ABGR	16	47.4	100.6	69.0
	LAOC	2	56.8	71.2	64.0
	PSME	14	26.8	78.9	66.8
TOTAL		6,509			

Sources/Notes: Ecoclass codes are used to record potential vegetation data on field forms and in computer databases; ecoclass codes for the Blue Mountains are summarized in Powell et al. (2007). Tree species is an alphanumeric code derived from the scientific genus and species names; species codes were taken from the original plant association field guides and they might not agree with contemporary coding from the national PLANTS database (USDA NRCS 2009). Tree count shows the number of site trees for a given species and ecoclass as recorded on occasion 1 CVS plots for all three Blue Mountains national forests. The minimum and maximum values of calculated site index are provided in columns four and five. The mean value of calculated site index, in feet, is provided in column 6. The sources of equations used for the site index calculations are provided in table 4.

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APPENDIX: SILVICULTURE WHITE PAPERS

White papers are internal reports, and they are produced with a consistent formatting and numbering scheme – all papers dealing with Silviculture, for example, are placed in a silviculture series (Silv) and numbered sequentially. Generally, white papers receive only limited review and, in some instances pertaining to highly technical or narrowly focused topics, the papers may receive no technical peer review at all. For papers that receive no review, the viewpoints and perspectives expressed in the paper are those of the author only, and do not necessarily represent agency positions of the Umatilla National Forest or the USDA Forest Service.

Large or important papers, such as two papers discussing active management considerations for dry and moist forests (white papers Silv-4 and Silv-7, respectively), receive extensive review comparable to what would occur for a research station general technical report (but they don't receive blind peer review, a process often used for journal articles).

White papers are designed to address a variety of objectives:

(1) They guide how a methodology, model, or procedure is used by practitioners on the Umatilla National Forest (to ensure consistency from one unit, or project, to another).

(2) Papers are often prepared to address ongoing and recurring needs; some papers have existed for more than 20 years and still receive high use, indicating that the need (or issue) has long standing – an example is white paper #1 describing the Forest's big-tree program, which has operated continuously for 25 years.

(3) Papers are sometimes prepared to address emerging or controversial issues, such as management of moist forests, elk thermal cover, or aspen forest in the Blue Mountains. These papers help establish a foundation of relevant literature, concepts, and principles that continuously evolve as an issue matures, and hence they may experience many iterations through time. [But also note that some papers have not changed since their initial development, in which case they reflect historical concepts or procedures.]

(4) Papers synthesize science viewed as particularly relevant to geographical and management contexts for the Umatilla National Forest. This is considered to be the Forest's self-selected 'best available science' (BAS), realizing that non-agency commenters would generally have a different conception of what constitutes BAS – like beauty, BAS is in the eye of the beholder.

(5) The objective of some papers is to locate and summarize the science germane to a particular topic or issue, including obscure sources such as master's theses or Ph.D. dissertations. In other instances, a paper may be designed to wade through an overwhelming amount of published science (dry-forest management), and then synthesize sources viewed as being most relevant to a local context.

(6) White papers function as a citable literature source for methodologies, models, and procedures used during environmental analysis – by citing a white paper, specialist reports can include less verbiage describing analytical databases, techniques, and so forth, some of which change little (if at all) from one planning effort to another.

(7) White papers are often used to describe how a map, database, or other product was developed. In this situation, the white paper functions as a 'user's guide' for the new product. Examples include papers dealing with historical products: (a) historical fire extents for the Tucannon watershed (WP Silv-21); (b) an 1880s map developed from General Land Office survey notes (WP Silv-41); and (c) a

description of historical mapping sources (24 separate items) available from the Forest's history website (WP Silv-23).

The following papers are available from the Forest's website: Silviculture White Papers

Paper #	Title
1	Big tree program
2	Description of composite vegetation database
3	Range of variation recommendations for dry, moist, and cold forests
4	Active management of dry forests in the Blue Mountains: silvicultural considerations
5	Site productivity estimates for upland forest plant associations of the Blue and Ochoco Mountains
6	Fire regimes of the Blue Mountains
7	Active management of moist forests in the Blue Mountains: silvicultural considerations
8	Keys for identifying forest series and plant associations of the Blue and Ochoco Mountains
9	Is elk thermal cover ecologically sustainable?
10	A stage is a stage is a stage…or is it? Successional stages, structural stages, seral stages
11	Blue Mountains vegetation chronology
12	Calculated values of basal area and board-foot timber volume for existing (known) values of canopy cover
13	Created openings: direction from the Umatilla National Forest land and resource management plan
14	Description of EVG-PI database
15	Determining green-tree replacements for snags: a process paper
16	Douglas-fir tussock moth: a briefing paper
17	Fact sheet: Forest Service trust funds
18	Fire regime condition class queries
19	Forest health notes for an Interior Columbia Basin Ecosystem Management Project field trip on July 30, 1998 (handout)
20	Height-diameter equations for tree species of the Blue and Wallowa Mountains
21	Historical fires in the headwaters portion of the Tucannon River watershed
22	Range of variation recommendations for insect and disease susceptibility
23	Historical vegetation mapping
24	How to measure a big tree
25	Important insects and diseases of the Blue Mountains
26	Is this stand overstocked? An environmental education activity
27	Mechanized timber harvest: some ecosystem management considerations
28	Common plants of the south-central Blue Mountains (Malheur National Forest)
29	Potential natural vegetation of the Umatilla National Forest
30	Potential vegetation mapping chronology
31	Probability of tree mortality as related to fire-caused crown scorch
32	Review of the "Integrated scientific assessment for ecosystem management in the interior Columbia basin, and portions of the Klamath and Great basins" – forest vegetation
33	Silviculture facts

Paper #	Title
34	Silvicultural activities: description and terminology
35	Site potential tree height estimates for the Pomeroy and Walla Walla ranger districts
36	Tree density protocol for mid-scale assessments
37	Tree density thresholds as related to crown-fire susceptibility
38	Umatilla National Forest Land and Resource Management Plan: forestry direction
39	Updates of maximum stand density index and site index for the Blue Mountains variant of the Forest Vegetation Simulator
40	Competing vegetation analysis for the southern portion of the Tower Fire area
41	Using General Land Office survey notes to characterize historical vegetation conditions for the Umatilla National Forest
42	Life history traits for common conifer trees of the Blue Mountains
43	Timber volume reductions associated with green-tree snag replacements
44	Density management field exercise
45	Climate change and carbon sequestration: vegetation management considerations
46	The Knutson-Vandenberg (K-V) program
47	Active management of quaking aspen plant communities in the northern Blue Mountains: regeneration ecology and silvicultural considerations
48	The Tower Fire…then and now. Using camera points to monitor postfire recovery
49	How to prepare a silvicultural prescription for uneven-aged management
50	Stand density conditions for the Umatilla National Forest: a range of variation analysis
51	Restoration opportunities for upland forest environments of the Umatilla National Forest
52	New perspectives in riparian management: Why might we want to consider active management for certain portions of riparian habitat conservation areas?
53	Eastside Screens chronology
54	Using mathematics in forestry: an environmental education activity
55	Silviculture certification: tips, tools, and trip-ups
56	Vegetation polygon mapping and classification standards: Malheur, Umatilla, and Wallowa-Whitman national forests
57	The state of vegetation databases on the Malheur, Umatilla, and Wallowa-Whitman national forests

Revision History

March 2014: minor formatting and editing changes were made; an appendix was added describing the white paper system, including a list of available white papers.